Chapter 9: Stability

Overview

Introduction

This chapter discusses stability, the ability of a vessel to return to an upright position after being heeled over. Many forces influence the stability of a vessel in the water and each type of vessel reacts differently. Coxswains must be aware of how internal forces (those caused by the boat's design and loading) and external forces (those caused by nature) affect the boat. With practice and experience, coxswains learn to anticipate how a vessel being piloted and a vessel being assisted will react to various internal and external forces. Recognizing unstable vessel conditions will lead to safe operations for both the boat crew and persons on a craft in distress.

In this chapter

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Section A. Safety and Risk Management Control

A.1. General

Safety of both the boat crew and those in distress is very important during any emergency evolution. Mishaps resulting in death or injury have occurred while Coast Guard boat crews were assisting vessels in distress. Accident investigation reports have revealed that injury or property damage often resulted from common sense and safety concerns being forgotten or ignored in the pressing urgency of the situation. If in the process of trying to assist another mariner you become injured or your vessel damaged, you become part of the problem instead of solving the problem. Chapter 4 of this manual provides general discussion on risk management.

A.2. Safety assessment and management guidelines

Emergency situations can cause people to panic or act before thinking despite the best of training and preparation. Therefore, boat crews must work together as a team to minimize any potential or immediate jeopardy for both civilian casualties and themselves. **Never** enter an emergency situation without first assessing the risk involved for the boat crew members and civilian victims (**Risk Assessment**), always be aware of the dynamics of the emergency situation (**Situational Awareness**), and implement a control plan that fits each unique emergency (**Stability Risk Management Plan**).

A.2.a. Risk assessment and management

Risk assessment starts with understanding why mishaps occur. Responsibility for identifying and managing risk lies with every member of the boat crew. Realistic training based on standard techniques, critical analysis, and debriefing missions will help every person in a boat crew to contribute to developing and implementing a **Risk Management Plan.** A Risk Management Plan identifies and controls risk according to a set of preconceived parameters.

- Make the best attempt to account for all persons.
- Attempt to have all lines, rigging, etc. removed from the water around the vessel to avoid fouling the screws.
- Have all required equipment ready and test run pumps.

Refer to Chapter 4 of this manual for a more complete discussion of areas where failure typically contributes significantly to serious mishaps.

A.2.b. Situational awareness

Situational Awareness is the accurate perception of the factors and conditions affecting the boat crew at a given time during any evolution. More simply stated, situational awareness is knowing what is going on around you at all times while continuing to perform the task assigned to you.

NOTE

Crews who have a high level of SITUATIONAL AWARENESS perform in a safe manner.

Any time you identify an indication that situational awareness is about to be lost, you must make a decision whether or not to continue with the rescue attempt. Everyone in the crew owns some responsibility for making these important decisions. The decision takes the form of **action/reaction** and **communication**. The person in charge of the boat makes the final decision but the boat crew has the responsibility to recognize dangerous situations and bring them to the attention of the coxswain.

A.2.c. Stability risk management plan

The entire crew must constantly watch for any loss of stability in their own vessel and that of the distressed craft. Do not assume that the coxswain has been able to observe all of the warning signs. Advise the coxswain of stability concerns that may have been overlooked and any warning signs. Use these warning signs as a guideline for a Stability Risk Management Plan.

- Observe the roll of your own boat and, for a distressed vessel, observe its roll upon approaching and when under tow.
- Be aware of external forces - wind, waves and water depth.
- Be aware of control loading, amount of weight and placement, on own and the distressed craft.
- If necessary, attempt to keep your equipment aboard your vessel when dewatering the vessel.
- Attempt to tow the vessel **only** after any loss of stability has been corrected.
- Adjust course, speed, or both as necessary to decrease rolling or listing.
- Avoid sharp turns or turns at high speed when loss of stability is possible.

- Maintain communication between the coxswain and crew.
- Keep the operational commander or parent unit informed of the situation through regular and frequent reports.

WARNING ☝

> When a vessel is visibly unstable (i.e., listing, trimmed to the bow/stern or when downflooding occurs) never make your vessel fast to or tow the distressed vessel. A flooded vessel may appear stable when it in fact is not. Compare the boats reaction to sea conditions with your own boat's movements.

Section B. Understanding Stability

Overview

Introduction

When a vessel is heeled over in reaction to some external influence, other than damage to the vessel, it tends to either return to an upright position or to continue to heel over and capsize. The tendency of a vessel to remain upright is its **stability**. The greater the tendency to remain upright, and the stronger the force required to heel the vessel over in any direction, the more stability the vessel achieves. The stability of a vessel in the water is very important to all members of a boat crew. Being able to anticipate how your vessel and the vessel you are assisting will react in any given set of circumstances is dependent on your knowledge of stability. Weight and buoyancy are the two primary forces acting upon a floating vessel that affect stability. The weight pushes the vessel down into the water. Buoyancy is the force that is pushing up from the water to keep the vessel afloat. The interaction of these two forces determines the vessel's stability.

In this section

These items are discussed in this section:

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Center of Gravity

B.1. Center of gravity

The center of gravity is the point at which the weight of the boat acts vertically downwards. Thus, the boat acts as though all of its weight were concentrated at the center of gravity. Generally, the lower the center of gravity, the more stable the vessel.

B.1.a. Changes in the center of gravity

The center of gravity of a boat is fixed for stability and does not shift unless weight is added, subtracted, or shifted. When weight is added, for example when a vessel takes on water, the center of gravity moves toward the added weight. When the weight is removed, the center of gravity moves in the opposite direction.

If a vessel has been damaged so that water is flowing in and out of a hole below the waterline, known as free communication with the sea, the result is a loss of buoyancy which generally means a significant reduction in stability.

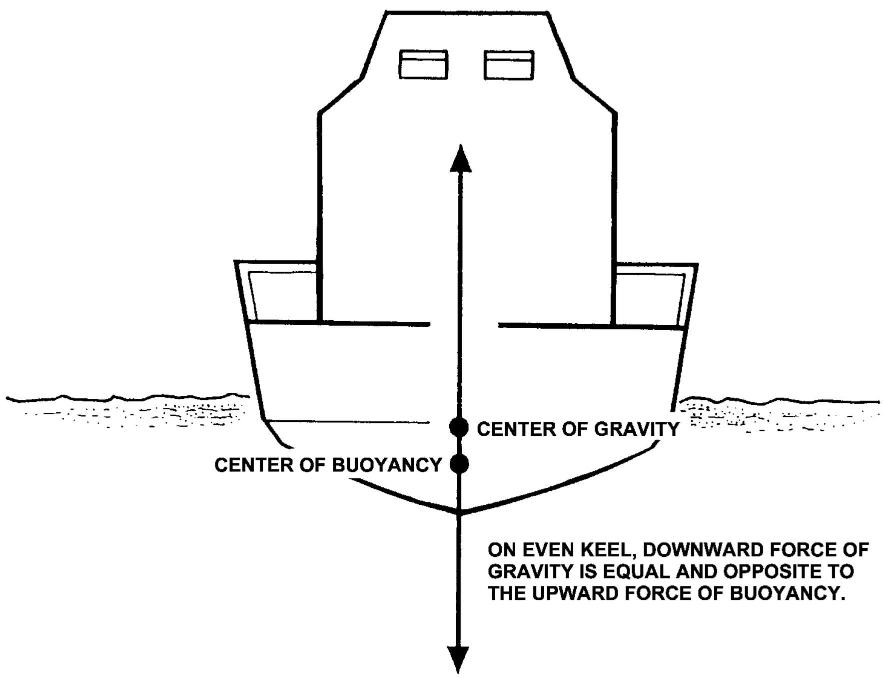
Buoyancy

B.2. Buoyancy	The buoyancy is the upward force of water displaced by the hull. The force of buoyancy keeps the boat afloat; however, it may be overcome and the boat will sink if too much weight is added.
B.2.a. Center of buoyancy	The center of buoyancy is the center of gravity of displaced water. Similar to the center of gravity, this is the point on which all upward/vertical force is considered to act. It lies in the center of the underwater form of the hull (See Figure 9-1).

Equilibrium

B.3. Equilibrium

When a boat is at rest, the center of buoyancy acting upwards/vertically is below the center of gravity acting downwards. A boat is considered to be in equilibrium. Equilibrium is affected by movement of the center of gravity or center of buoyancy or by some outside forces, such as wind and waves (See Figure 9-1).



Stability In Equilibrium
Figure 9-1

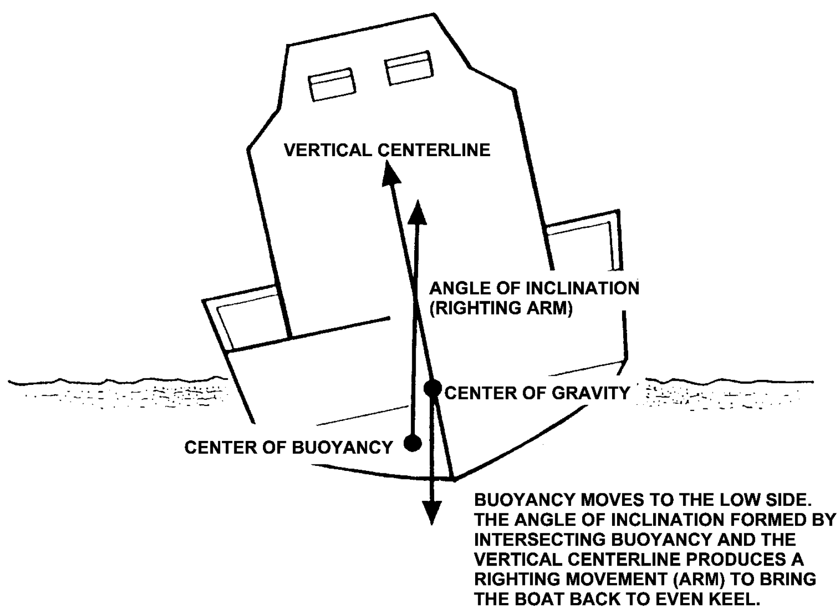
B.3.a. Rolling

When a boat rolls, the force of the center of gravity will move in the same direction as the roll. The downward force of gravity is offset by the upward force of buoyancy and causes the boat to heel.

B.3.b. Heeling

In heeling, the underwater volume of the boat changes shape causing the center of buoyancy to move.

The center of buoyancy will move towards the part of the hull that is more deeply immersed. When this happens the center of buoyancy will no longer be aligned vertically with the center of gravity. The intersection of the vertical line thru the center of bouyancy and the vertical centerline is called the metacenter. When the metacentric height (the distance between center of gravity and metacenter) is positive, that is the metacenter is above center and gravity, the center of buoyancy shifts so that it is outboard of the center of gravity the boat is considered to be stable, and the forces of buoyancy and gravity will act to bring the boat back to an upright position. If the center of buoyancy is inboard of the center of gravity, that is the metacentric height is negative, the forces of buoyancy and gravity will tend to roll the boat further towards capsize (See Figure 9-2).



Heeling
Figure 9-2

B.3.c. Listing

If the center of gravity is not on the centerline of the boat, the boat will heel until equilibrium is reached with the center of buoyancy and center of gravity in alignment. This condition is referred to as **list**.

NOTE

Heeling is a temporary leaning, listing is a permanent leaning, and both are different from rolling which is a side-to-side motion.

Types of Stability

B.4. Types of stability

A boat has two principle types of stability:

- Longitudinal
- Transverse

A boat is usually much longer than it is wide. Therefore, the longitudinal plane (fore and aft) is more stable than its transverse plane (beam).

B.4.a. Longitudinal (fore and aft) stability

Longitudinal (fore and aft) stability tends to balance the boat, preventing it from pitching end-over-end (pitch poling). Vessels are designed with enough longitudinal stability to avoid damage under normal circumstances. However, differences in vessel design varies the longitudinal stability characteristics of different vessels depending on the purpose for which a vessel is designed. Some vessels can suffer excessive pitching and offer a very wet and uncomfortable ride during rough sea and weather conditions. Such an uncomfortable ride often affects the endurance and capability of people on vessels you are assisting.

B.4.b. Transverse (athwartships) stability

Transverse (athwartships) stability tends to keep the boat from rolling over (capsizing). Additional weight above the center of gravity increases the distance from the center of gravity up to the center of buoyancy. As a result, stability is also decreased. Removal of weight from below the center of gravity also decreases stability. If the center of gravity is raised enough the boat will become unstable.

Moment and Forces

B.5. Moment and forces

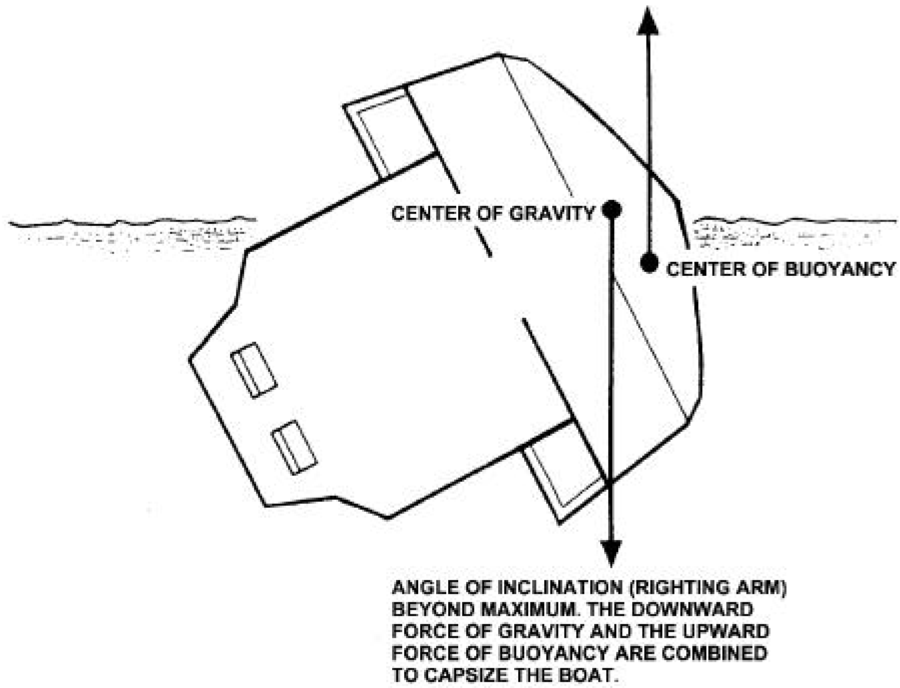
The force that causes a vessel to return to an even keel, or upright position is called the vessel's **moment**. Both static and dynamic forces can reduce stability and moment. Moments, and the internal and external forces that act to increase or decrease the righting moment, are important factors in determining the stability of a vessel at any given point in time.

B.5.a. Righting moment and capsizing

A **righting moment** is the force causing a vessel to react against a roll and return to an even keel. Generally, the broader a boat's beam, the more stable that boat will be and the less likely it is to capsize. For any given condition of loading, the center of gravity is at a fixed position. As a boat heels, the center of buoyancy moves to the lower side of the boat forming an angle of inclination. Larger changes in the movement of the center of buoyancy will result with any given angle of heel. This change provides greater righting movement, up to a maximum angle of inclination.

Too much weight added to the side of the vessel that is heeled over can overcome the forces supporting stability and cause the vessel to capsize. (See Figure 9-3.)

A boat may also capsize when aground as the volume of water beneath the vessel decreases and the vessel loses balance. As the amount of water supporting the vessel is reduced, there is a loss of buoyancy force being provided by that water. In addition, the upward force acting at the point of grounding will increase and cause the unsupported hull to fall to one side.



Righting Moment and Capsizing
Figure 9-3

B.5.b. Static and dynamic forces

Unless acted upon by some external force, a boat that is properly designed and loaded remains on an even keel. The two principle forces that affect stability are **static** and **dynamic** forces.

1) Static forces are caused by placement of weight within the hull. Adding weight on one side of a boat's centerline or above its center of gravity usually reduces stability. Flooding or grounding a boat makes it susceptible to static forces which may adversely affect stability.
2) Dynamic forces are caused by actions outside the hull such as wind and waves. Strong gusts of wind or heavy seas, especially in shallow water, may build up a dangerous sea tending to capsize a boat.

For a boat crew member this understanding is useful when approaching a vessel to provide assistance. Observing the vessel's roll can provide some initial indications about the stability of the vessel.

- Watch the time required for a complete roll from side to side. The time should remain about the same regardless of the severity of the angle or roll.
- If the time increases significantly or the boat hesitates at the end of the roll, the boat is approaching or past the position of maximum righting effect. Take immediate steps to decrease the roll by changing course or speed or both.

B.6. Vessel design

General vessel design features that influence stability include:

- Size and shape of the hull
- Draft of the boat (the distance from the surface of the water to the keel)
- Trim (the angle from horizontal at which a vessel rides)
- Displacement
- Freeboard
- Superstructure size, shape, and weight
- Non-watertight openings

Many of these features are discussed in Chapter 8, *Boat Characteristics*.

Section C. Losing Stability

Overview

Introduction

A vessel may be inclined away from its upright position by certain internal and external influences such as:

- Waves
- Wind
- Turning forces when the rudder is put over
- Shifting of weights on board
- Addition or removal of weights
- Loss of buoyancy (damage)

These influences exert heeling moments on a vessel causing it to list (permanent) or heel (temporary). A stable boat does not capsize when subjected to normal heeling moments due to the boat's tendency to right itself (righting moment).

In this section

These items are discussed in this section:

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Stability After Damage

C.1. General

When assisting a damaged vessel consider that any change in stability may result in the loss of the vessel. The added weight of assisting personnel or equipment may cause the vessel to lose its righting moment, lose stability, and capsize. This consequence, and the danger involved, must be considered when determining risk to avoid harm to the crew and further damage or loss of a vessel.

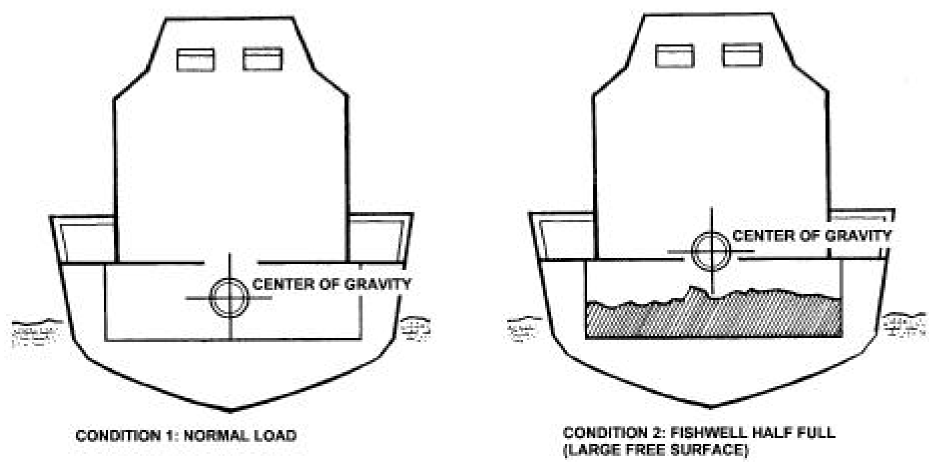
Free Surface Effect

C.2. General

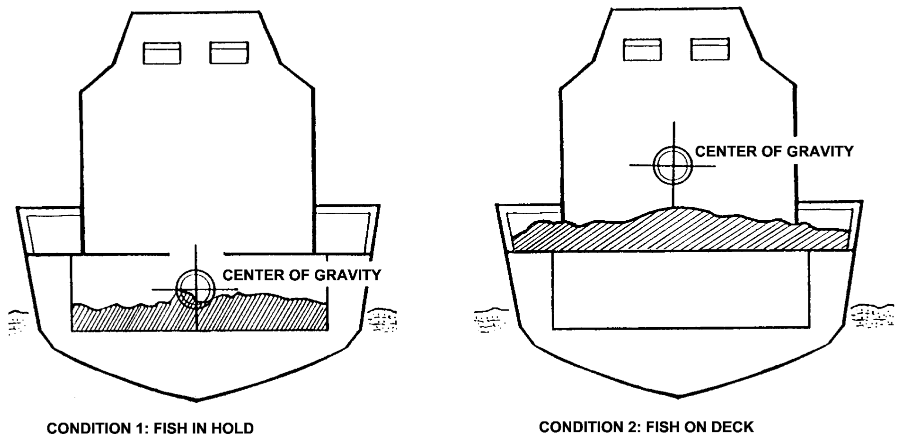
NOTE

Note that the area of free surface is very important, and in particular its width. If the free surface area doubles in width, its adverse effect on stability will change by a factor of four.

Compartments in a vessel may contain liquids as a matter of design or as a result of damage. If a compartment is only partly filled, the liquid can flow from side to side as the vessel rolls or pitches. The surface of the liquid tends to remain parallel to the waterline. Liquid that only partly fills a compartment is said to have **free surface** and water in such a compartment is called **loose water**. When loose water shifts from side to side or forward and aft due to turning, speed changes, or wave action, the vessel does not want to right itself. This causes a loss of stability. This can cause the vessel to capsize or sink. A cargo of fish free to move about inside a compartment will have the same effect, a condition commonly found on fishing vessels (See Figures 9-4 and 9-5).



Effects of Free Surface
Figure 9-4



Effects of Load Weight
Figure 9-5

C.3. Corrective actions

Corrective actions include

- Minimize the number of partially filled tanks (fuel, water, or cargo); ballast with sea water as necessary.
- Maintain fish wells completely empty or filled at all times.
- Prevent cargo such as fish from rolling back and forth on the deck.

Free Communication with the Sea

C.4. General

Damage to the hull of a vessel can create free communication with the sea, the movement of sea water into and out of the vessel.

C.5. Corrective actions

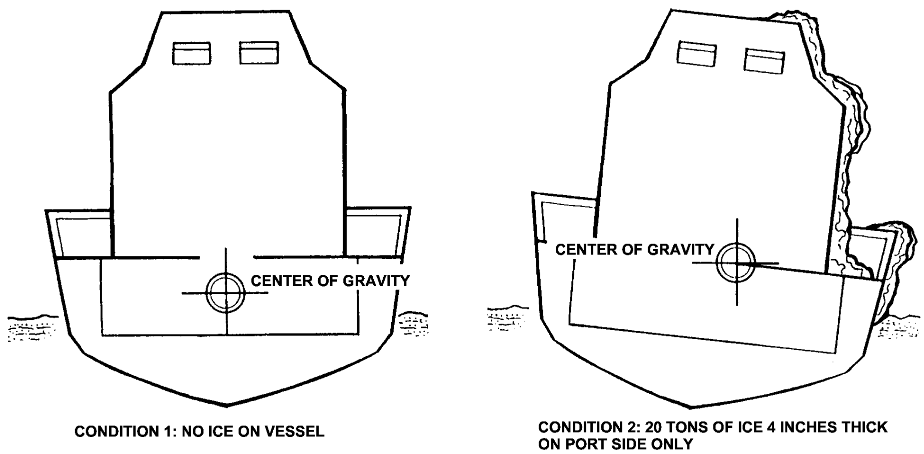
Corrective actions include:

- Patch the hull opening.
- Place weight on the high side to decrease the list toward the damaged side.
- Remove weight above the center of gravity on the damaged side.

Effects of Icing

C.6. General

Icing can increase the displacement of a boat by adding weight above the center of gravity and causing it to rise. This can cause a vessel to heel over and greatly reduce stability. Sea swells, sharp turns, or quick changes in speed can capsize a vessel that has accumulated ice on its topside surfaces. (See Figure 9-6.)



Effects of Icing
Figure 9-6

C.7. Corrective actions

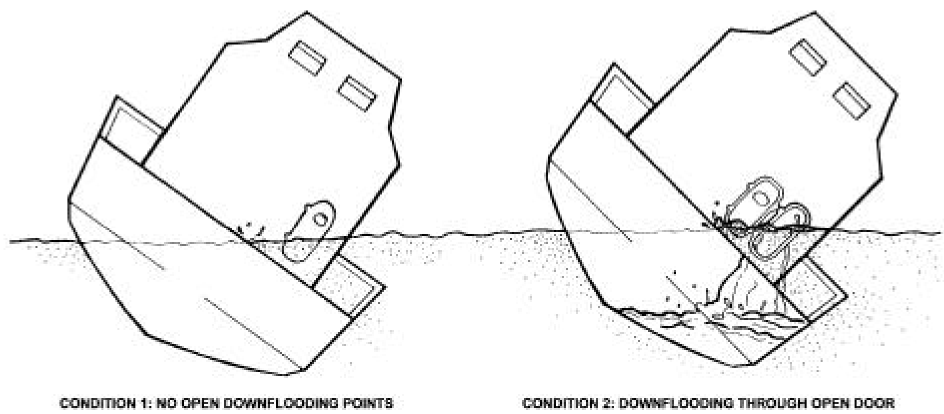
Corrective actions include:

- Change course, speed or both to reduce freezing spray and rolling.
- Physically remove the ice.

Effects of Downflooding

C.8. General

Downflooding is the entry of water into the hull resulting in progressive flooding and loss of stability. Vessels are designed with sufficient stability and proper righting moments as long as they are not overloaded. These design features cannot compensate for the carelessness of a boat crew who fails to maintain the watertight integrity of a vessel and allow it to needlessly take on water. (See Figure 9-7.)



Effects of Downflooding
Figure 9-7

C.9. Corrective actions

Corrective actions include:

- Keep all watertight fittings and openings secured when a vessel is underway.
- Pump out the water.

Effects of Water on Deck

C.10. General

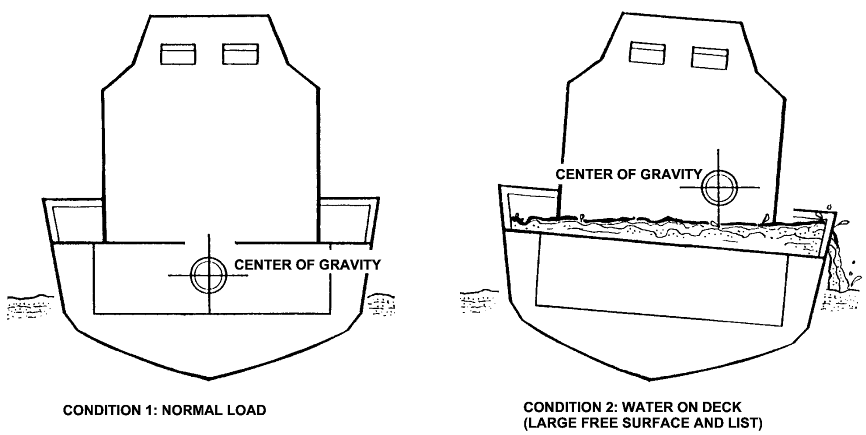
Water on deck can cause stability problems by:

- Increasing displacement (increasing draft and decreasing stability and trim).
- Contributing to free surface effect.
- Amplifying the rolling motion of the vessel which may result in capsizing.

C.11. Corrective actions

Corrective actions include:

- Decrease trim, increase freeboard.
- Change course, speed or both.
- Ensure drain openings are unobstructed (See Figure 9-8).



Effects of Water on Deck
Figure 9-8